Optical and Mechanical Resilience of Reduced Coating Diameter Fibers

Application Note

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Introduction

Miniaturization of cables and associated hardware is a major trend in the optical fiber cable telecommunications industry. This is born out of a necessity to improve installation space-efficiency and accelerate penetration of fast optical fiber-based bandwidth service coverage to subscriber areas which are difficult to reach or costly to service. Urban areas can be especially challenging for network operators when trying to deploy high-fiber-count cables in underground duct infrastructure that is either congested or duct-size restricted. Smaller diameter, higher fiber-density micro cables offer several distinct advantages: more efficient utilization of duct space, easier handling, and faster installation. Smaller and more lightweight cables can be deployed quickly and more efficiently by blowing into smaller duct sizes. Additionally, smaller form factor cable and hardware can help reduce costs associated with packaging, storage, and freight. The new generation of micro cables require smaller diameter optical fibers that occupy less space and offer greater optical transmission resilience in confined spaces. Reduced coating diameter fibers started to emerge early in the last decade and any initial concerns in the industry about the standardization and multiple sourcing of these products have been addressed by the modification of IEC 60793-2-50 in 2018 to include an option of uncolored coating diameter of 180 to 210 microns across single-mode fiber types. Reduced diameter fiber options are now offered by majority of market-leading fiber suppliers.

Corning's first reduced coating diameter product was SMF-28® Ultra 200 fiber which features a reduced coating diameter of 200 microns that is beneficial for high fiber-density outside plant cabling (OSP) and provides 100% ITU-T G.652.D backwards compatibility with enhanced bending capability [1]. In response to the growing market acceptance of lower coating diameter product, Corning is expanding its portfolio and now offers market-leading reduced coating diameter fibers in a 190-micron form factor to help further increase fiber density in a growing number of cable application spaces. This application note explains some of the key features of these advanced, reduced coating diameter fiber types and how the superior transmission capability of the fiber can be maintained whilst continuing to minimize potential glass damaging mechanisms that might otherwise be aggravated by the reduced thickness of the surrounding coating.

As the market continues to demand higher fiber-count cables, Corning will continue to position itself for future telecommunication growth and enabling our customers to install market-leading optical fibers into their networks.

Reduced Diameter Fiber Coating

Conventional single-mode optical fibers that have become the foundation of modern-day optical telecommunication networks feature a protective coating layer with a nominal outside diameter of between 242 to 250 microns depending on application. Since Corning developed the first low-loss fibers in the 1970s, optical fiber technologies have evolved tremendously. Enhancements in both glass and coating technologies have improved optical transmission capabilities and the protective qualities of coating that preserve the optical and mechanical properties of the fiber. For decades, Corning's optical fibers have been mechanically durable and optically reliable across numerous outside cabling applications deployed worldwide. Corning has also developed fibers with a reduced

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diameter coating to enable the development of smaller diameter, high fiber-density cables [2]. These fibers have glass technology which helps to advance the optical performance levels of the fiber and an optimized coating which maintains its protective functions despite the reduction in coating thickness. Figure 1 illustrates the two main functions of Corning's dual layer CPC® protective: 1) The softer inner layer which has a lower Young's modulus and low glass transition temperature, preserves the fiber's optical performance properties during its operational lifetime, 2) the hard outer layer serves to protect the inner coating layer and the glass from mechanical damage during processing, installation, and expected service life. The smaller form factor of ~30% compared to 242 microns presents the opportunity for significant increase in the fiber density of cables and network capacity in a space-constrained environment.

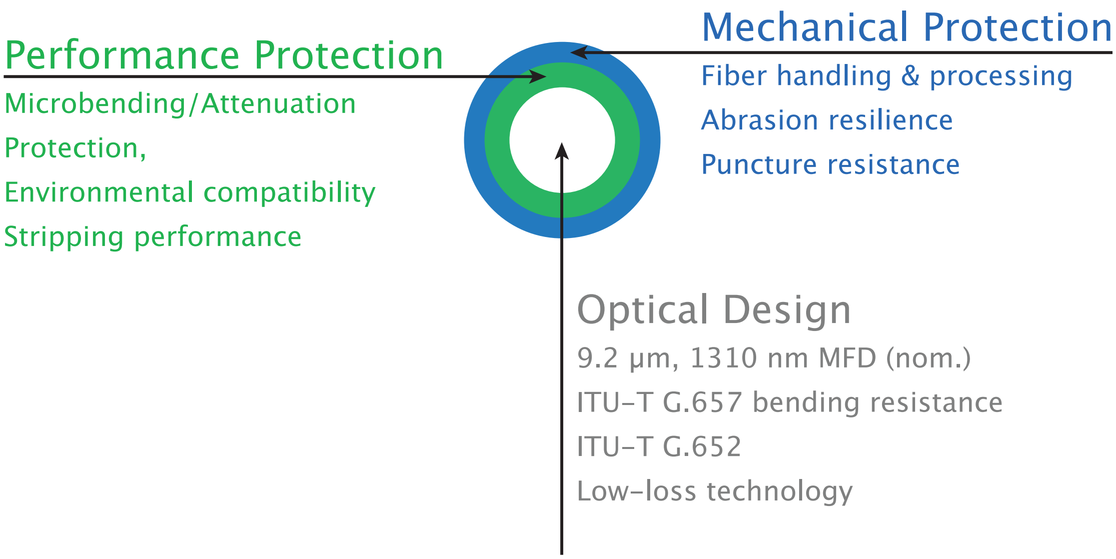

Figure 1. Two main principle functions of the dual-layer Corning CPC® protective coating and key design aspects of the central glass fiber.

Mechanical Protection and Fiber Handling Properties

The mechanical protective qualities of the fiber coating are dependent on the properties of the outer coating layer. To achieve the desired levels of coating toughness requires the outer coating to have high fracture toughness and sufficient radial thickness to protect the glass from damage during handling and cable processing, and to remain effective during its operational lifetime. Corning has studied the coating toughness properties over many years to understand how to design advantaged materials that enable reduced diameter fiber to be deployed in the interest of higher fiber density and maximizing network capacity [3,4].

The polymer material for the outer layer of the current generation of Corning's CPC® coating system was designed to have higher puncture resilience than the preceding versions. However, an optical fiber with a reduced coating diameter will have lower puncture resistance than an equivalent fiber with a ~242-micron coating layer because of the reduced thickness of the outer material. With the consequential reduction in protective material, a network operator or cable manufacturer might be concerned and expect to encounter more breaks per kilometer that can be attributed to process related puncture mechanisms. However, the as-drawn strength of Corning's reduced coating diameter fiber products is in fact unchanged from the ~242 micron. With the exception of die and tooling sizes being proportionately smaller for reduced coating diameter fibers, processing and fiber-cable making equipment is generally interchangeable for ~242-micron fiber. In almost 10 years since reduced coating diameter fibers have been deployed, no concerns in fiber fragility have raised by the industry. Therefore, if adopted practices are maintained that already minimize external mechanisms that could cause glass damage, for example coating puncture, then the risk of increased break occurrences is minimal.

Some of the external damage mechanisms that could be more impactful for a fiber with lower coating diameter and that need particular attention paid to control are as follows; whip (i.e. penetration of the coating from flailing fiber ends), abrasion from an uneven fiber contact surface, abrasion from fiber running across a static contact surface, e.g. seized pulley guide, or puncture by dirt or accumulated debris captured between the fiber and a contact surface, and manual handling during equipment thread-up.

After several years of experience running reduced coating diameter fiber since introduction in 2014, Corning has reviewed cable factory break rates in one of the global factories where both conventional and reduced coating diameter fiber is processed in large volumes. Equivalent low break rates are found to be achievable in both the coloring and buffering processes for both versions of the product. With close attention to routine cleaning of the fiber contact points on the production equipment machinery (pulleys, rollers and guide dies) and diligent housekeeping in the general vicinity of the manufacturing equipment, the reduction in the coating diameter does not necessarily introduce an increased break rate.

Based on these experiences, some suggestions that could assist a cable maker when starting to process reduced coating diameter fiber for the first time are as follows:

- Consider increasing the frequency of line inspection and cleaning regime of fiber processing equipment and fiber-contact component inspection. In addition to routine cleaning and inspection regimes in step with equipment utilization, less frequent but regular deep cleaning of each machine with fiber contact surfaces is suggested. Fiber contact surfaces that are found to be damaged in a manner that could nick the fiber coating should be replaced immediately, all rotating parts that contact the fiber should be checked to ensure that they rotate freely, and line operators should be educated in the importance of completing the cleaning regimes thoroughly.
- Tighter specifications for fiber contact part surface finishes should be considered.
- Use reduced diameter mechanical grade fiber, rather than conventional diameter mechanical grade fiber, for the setting up of lines that will process reduced diameter fiber. Please contact your Corning account manager to receive the necessary mechanical grade materials to perform these set-ups.
- Re-check fiber pay-out paths observe the correct pay-out tension and alignment as the fiber is un-wound from the spool. Excessive pay-out tension and un-controlled fiber pay-out angle increases risk of fiber contact with machinery parts that can cause damage and breakages.

Corning's reduced diameter fibers were also tested to measure coating strip force against existing requirements for conventional fibers in accordance with the sectional requirements of IEC 60793-2-50 for type B fibers [5]. Figure 3 shows the peak and average measured coating strip force for conventional coating diameter and reduced coating diameter fibers using the same coating type. These two particular studies agree well with fiber and cable processing and handling trials, during which no changes to any fiber handling or fiber processing practices were deemed necessary, other than the required use of smaller sized machine tooling to make best use of the smaller form factor.

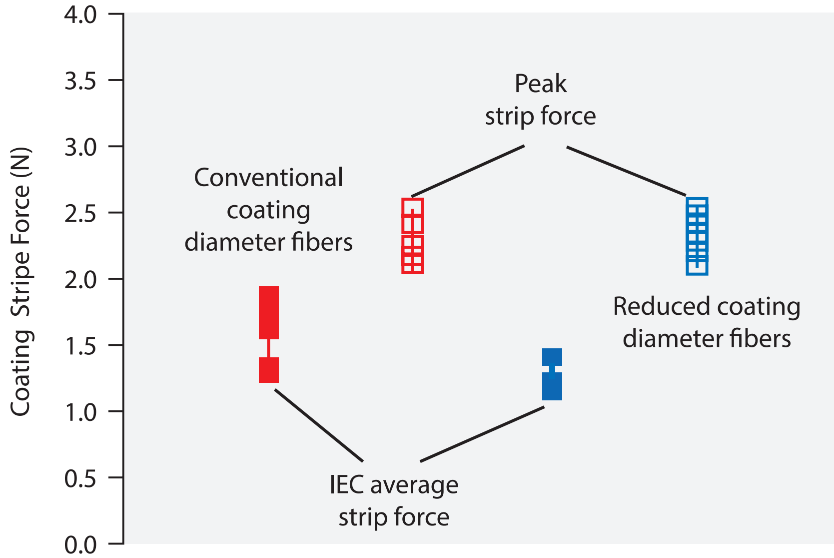

Figure 3. Comparison of coating stripe force: Conventional vs. reduced coating diameter fibers.

As the tensile strength and mechanical reliability properties of optical fiber are determined by the glass and distribution of lower strength flaws present in the cladding surface, reduced coating diameter fiber products share the same mechanical specifications as conventional products. Furthermore, fiber strength and reliability models developed by Corning continue to apply for reduced coating diameter fiber. The applied stress guidelines that set out safe stress limits for tensile stress and bending stress applications that demand near zero failure risk or managed risk, continue to apply for Corning's reduced coating diameter fibers [6].

Fusion Splicing: Performance Compatibility

The fusion splicing performance of reduced coating diameter ITU-T G.652.D fiber when spliced to conventional 242-micron ITU-T G.652.D fiber type is equivalent to splicing two conventional 242-micron fibers together due to the same and shared mode-field diameter (MFD) specifications. The adoption of ITU-T G.657.A1 and ITU-T G.657.A2 fibers in high fiber-count outside plant cables, which feature smaller MFD, has been deferred by some network operators due to perceived concerns over splice compatibility with the existing network installed base of legacy ITU-T G.652 fibers. Earlier versions of ITU-T G.657 fibers derived some enhanced optical bending resistance from their smaller MFD, which is typically 8.6 - 8.8 microns and smaller than legacy ITU-T G.652 fibers that have a nominal MFD of 9.2 micron. Corning reduced coating diameter fibers that are ITU-T G.657.A1 and ITU-T G.657.A2 compliant have a nominal MFD of 9.2 micron which maintains MFD compatibility with legacy ITU-T G.652.D fibers to alleviate concerns during cable jointing and termination in the field.

When splicing reduced coating diameter products, some caution needs to be taken to ensure that the coating layer is stripped to a sufficiently long distance, such that only the fully stripped portion of the glass of the fiber lies within the V-groove holding mechanism of the fusion splicer. This is particularly true if attempting to splice conventional coating diameter to reduced coating diameter product as the effect of the coating in the two V-grooves will be different and could lead to a core alignment issue. Corning Application Engineers have observed that not all single fiber strippers strip reduced coating diameter fibers as cleanly as ~242-micron fibers. Therefore, extra care should be taken to ensure all coating is removed with an alcohol wipe before attempting to splice. Stripping tools are also available that are marketed as offering enhanced performance with lower coating diameter. The same concerns exist in regard to handling ribbonized reduced diameter fibers. Care must be taken to ensure no matrix material (which bonds the ribbon) 'overhangs' affecting the quality of the splice.

During fusion splicing studies of reduced diameter single-mode fiber products, using both core- and cladding-alignment modes and standard splicing recipes found on all the commercially available splicing machines tested, a typical splice loss of 0.02 ~ 0.03 dB was achievable. Reduced diameter fiber was identifiable as ITU-T G.652.D single-mode fiber with all splicing machines tested – including independent studies conducted by a well-known fusion splicer equipment manufacturer.

Core Alignment Splicing: Reduced coating diameter fiber vs reduced coating diameter fiber w/ similar MFD

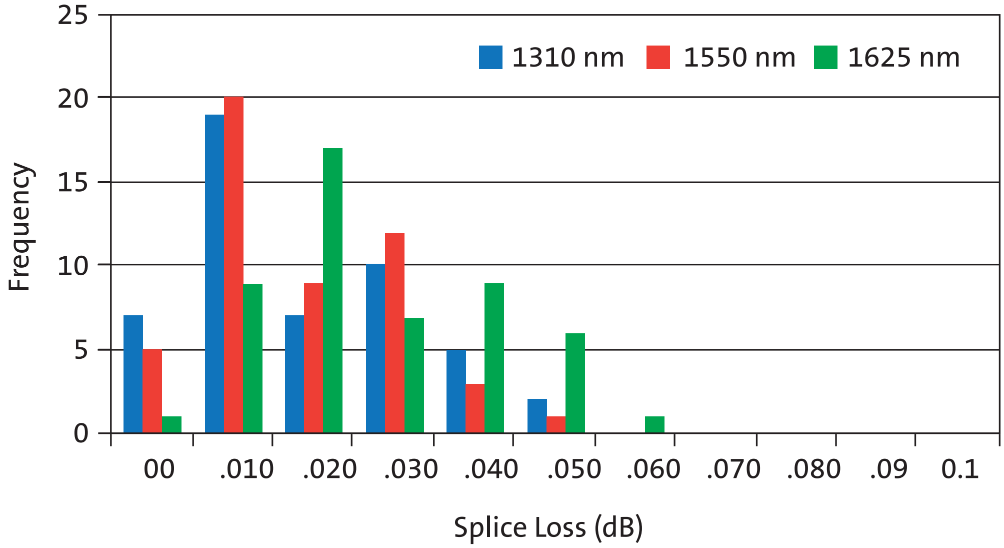

Figure 4. Representative splice loss of ITU-T.G652.D reduced diameter fiber spliced to itself.

Core Alignment Splicing: Reduced coating diameter fiber vs convention coating diameter fiber w/ similar MFD

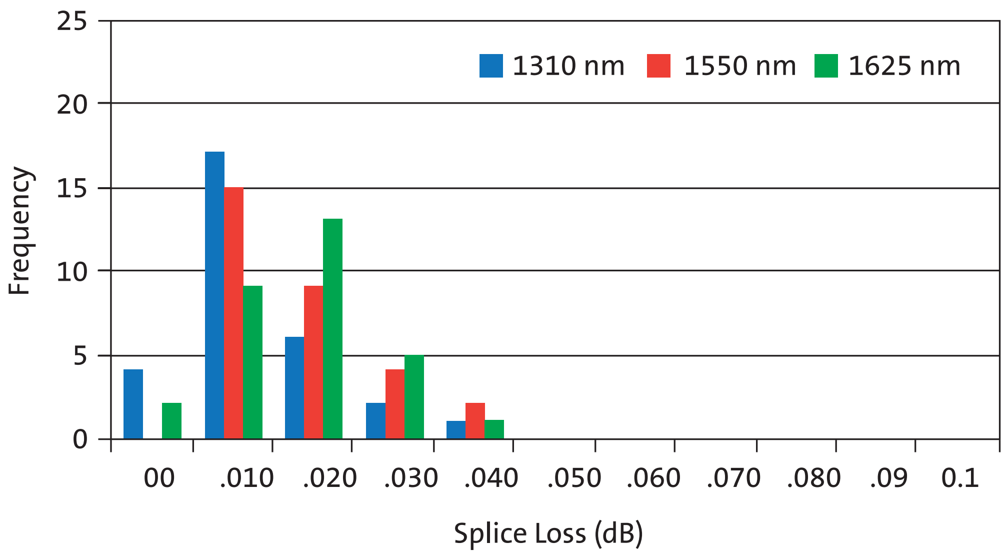

Figure 5. Representative splice loss of ITU-T.G652.D reduced diameter fiber spliced to convention diameter fiber.

Summary

Reduced coating diameter optical fiber products have successfully enabled the introduction of densely packed mini-cables for more space efficient fiber deployment in access networks. Having proven their value over the previous decade, this concept is now being extended to other application spaces. As a result, Corning is increasing the number of products that are being made available in the smaller form version. With a strong track record, those experiences from the earlier generation of products have been collected to provide information and recommendations for cablers and installers who may be experiencing reduced diameter coating fiber for the first time. With correct procedures in place, Corning's reduced coating diameter fiber can be operated with the same confidence as derived from Corning's conventional coating diameter products.

References

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